MODELLING OF RAINFALL-RUNOFF RELATIONSHIP AT SUBCATHCHMENT OF UNIVERSITI MALAYSIA PAHANG, GAMBANG CAMPUS

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ABSTRACT

Universiti Malaysia Pahang (UMP) has drainage system that is insufficient to cattle the capacity of the runoff especially in Block W due to urbanization. Drainage design in UMP not take account the future development so, it's not able to function properly. Before this, drainage system in UMP is design for the Malaysia Electrical Corporation's (MEC) factory. Based on "Manual Saliran Mesra Alam" (MASMA) the design of minor drainage is for five years Average Recurrence Interval (ARI). Due to that design year, UMP exposed to serious flash flood. Therefore, this study is to determine the rainfall-runoff relationship, analyse rainfall-runoff data using Snyder and Clark method in HEC-HMS computer program. The study area is the drainage system with 0.11 slopes of UMP surrounding laboratories, Block W and new buildings with 0.8 m^2. From this study, it was found that runoff is depending on the rainfall intensity. Using HEC-HMS gave satisfying results and it is suitable for simulating future urbanization. In this software, hydrology parameter such as loss rate, transform and base flow are important to simulate the data. However, it is difficult to obtain accurate and suitable parameters for a catchment area. Nine storm event were used for calibration in order to get an optimum values for catchment area of UMP. After the comparison between Snyder and Clark Time Area method, Snyder method is the best method for UMP area with the Efficiency Index of 75.09%.

ABSTRAK

Universiti Malaysia Pahang (UMP) mempunyai sistem saliran yang tidak mencukupi untuk menahan kapasiti air larian terutamanya di Block W akibat daripada pembangunan. Reka bentuk saliran di UMP tidak mengambil kira pembangunan pada masa hadapan, jadi ia tidak berfungsi dengan baik. Sebelum ini, sistem saliran di UMP direka untuk kilang Malaysia Electrical Corporation (MEC). Berdasarkan "Manual Saliran Mesra Alam" (MASMA), sistem saliran ini direka berdasarkan sistem saliran minor untuk lima tahun Purata Kala Kembali (ARI). Akibat daripada reka tahun tersebut, UMP terdedah kepada banjir kilat yang serius. Maka kajian ini untuk mengetahui kaedah yang terbaik untuk menganalisis data hujan-air larian dengan menggunakan kaedah Snyder dan Clark Time Area dalam perisian HEC-HMS. Kawasan kajian mempunyai sistem saliran dengan kecerunan 0.011 yang meliputi makmal , Blok W dan bangunan-bangunan baru dengan keluasan 0.8 m^2. Daripada kajian, didapati air larian bergantung kepada kelebatan hujan. Dengan menggunakan perisian HEC-HMS akan memberikan keputusan yang memuaskan dan bersesuaian untuk simulasi pembangunan pada masa hadapan. Dengan meggunakan perisian ini, parameter seperti "Loss Rate", "Transform" dan aliran dasar adalah penting untuk data simulasi. Tetapi sukar untuk mendapatkan parameter yang tepat dan sesuai untuk kawasan tadahan. Sembilan peristiwa hujan digunakan untuk kalibrasi bertujuan untuk mendapatkan nilai optimum untuk kawasan tadahan di UMP. Selepas perbandingan antara kaedah Snyder dan Clark Time Area, didapati Snyder adalah kaedah yang terbaik untuk kawasan UMP dengan Indek Kecekapan sebanyak 75.09%.

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m^3	-	Meter cube
m^2	-	Meter square
km	-	Kilometer
mm	-	Millimeter
m^3/s	-	Meter cube per second
n	-	Number of subareas
t_r	-	Effective rainfall duration
t_R	-	Effective duration
t_{IR}	-	Basin lag
t_l	-	Basin lag time
t_b	-	Basin time
q_p	-	Peak direct runoff rate
q_{pR}	-	Peak discharge per unit watershed area
q_u	-	Unit peak discharge
Q_p	-	Peak runoff
A	-	Drainage area
i	-	Rainfall runoff intensity
I_a	-	Initial abstraction including surface storage, intercept and Infiltration prior to runoff
P	-	Accumulated rainfall (potential maximum runoff)
L	-	Length
L_c	-	Distance in kilometers (miles) from the outlet to a point On the stream nearest the centroid
C_1	-	0.75 (1.0 for English units)

C_t	-	Coefficient represent variation in watershed slopes and storages characteristic
C_2	-	2.75 (640 for English units)
C_p	-	Coefficient represents the effects of retention and storage
C_w	-	1.22 (440 for English units) for 75% and 2.14 (770 for English units) for 50%
C_A	-	Routing coefficients
C_B	-	Routing coefficients
C_3	-	5.56 (1290 for English system)
cfs	-	Cubic square foot
km^2	-	Kilometer square
u	-	Ratio of the total runoff volume to the area under the dimensionless hydrograph
W_{50}	-	Widths of the UH at values of 50%
W_{75}	-	Widths of the UH at values of 75%
Q	-	Flow rate of runoff
R	-	Hydraulic radius
I_t	-	Average inflow to storage at time *t*
min	-	Minute
S	-	Slope
S_t	-	Storage at time *t*
P	-	Wetted parameter
t_c	-	Time concentration
T_{lag}	-	Snyder's standard lag (hours)
O_t	-	Average outflow during period *t*
Q_i	-	Observed discharge at time,i

Q_{ag}	-	Mean of observed discharge
R	-	Storage attenuation coefficient
N	-	Number of discharge data
n	-	Manning roughness coefficient
F_i	-	Simulated discharge at time,i
$\sum$	-	Summation
SS	-	Sum of square

LIST OF ABBREVATION

UMP	Universiti Malaysia Pahang
MEC	Malaysia Electrical Corporation
MASMA	Manual Saliran Mesra Alam
ARI	Average Recurrence Interval
HEC-HMS	Hydrologic Engineering Centre Hydrologic Modelling System
JPS	Jabatan Pengairan dan Saliran
DID	Department of Irrigation and Drainage (DID)
SCS	Soil Conservation Service
SWMM	Storm Water Management Model (SWMM)
HEC-RAS	Hydrologic Engineering Center-River Analysis System
UH	Unit Hydrograph

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Malaysia has been a successful developing country in South East Asia which has the rapid of development growth rate. The continuous growth of population and massive development will affect the physical characteristics of an area and change the hydrological practice. Increasing number of impervious and then combined with heavy rain and poor drainage systems have reduce the amount of water to infiltrated into the soil, thus increase surface runoff.

In Malaysia, flood is the most common natural hazard. The peninsula is geographically located in the wet equatorial tropics where seasonal monsoon winds bring forth heavy rain from Siberia spells generating extensive seasonal monsoon floods along the east coast of Kelantan, Terengganu, Pahang and East Johore. This is especially in the peninsula's East Coast region where the occurrence of such flood is considered a way of life (Chan, 1995).

It is frequent and widespread, often escalating into disaster which cripples the economy, communications, public services and result in property damage and loss of life (Chan, 1996). Therefore, estimation of surface runoff from upstream area is important in establishing flood control in downstream area.

Unplanned development and rapid urbanization process can cause certain area change the originality of earth and can lead to disasters. Flash flood is usual disaster occurring in Kuala Lumpur. As reported through the news, the flash flood cause the road submerged and thousands of road users were stuck in the traffic jam on several areas in Kuala Lumpur. Then, the Northeast Monsoon brought heavy rain through series of extreme and persistent storm causing devastating monsoon flood. In addition, early year 2013, two students became victims of the flood that occurred in Machang, Kelantan. This disaster gives serious impact when there is loss of life

` When the rivers and drainage are not able to endure the sudden water capacity at the catchment area, flash floods happen. This phenomenon has caused serious flash flooding in big cities in Malaysia nowadays. The flash flood occurred in Kuantan, Pahang, on 25 December 2012 is caused several roads and premises, and shopping malls had to close for business. At the end of year 2013, the worst flood occurred at East Coast of Malaysia that left Kuantan, almost paralysed during the end of 2013.

1.2 PROBLEM STATEMENT

In monsoon season 17 December 2014, flooding problem occurred in Kolej Kediaman II, Universiti Malaysia Pahang (UMP), Gambang Campus as a result of development in catchment area and obstruction in waterway flow as shows in Figure 1.1. While natural conditions are shown to foster and create monsoon floods, the incident of flash flood, particularly in Universiti Malaysia Pahang is largely the consequence of human action.

Rainfall will infiltrate more in an undeveloped area (pervious) compare to developed area (impervious). So, the large amount of rainfall in a developed area, only a little amount will infiltrate in soil and the rest of them will flow to the lower level of the ground as a runoff then the water flow to the drain. One of the reason flash floods happen in UMP due to clogging of drain cause by human activities shows in Figure 1.2. The rising student population contributes to high disposal of rubbish and prevent the smooth flow of water. The drain unable to support the amount of water thus an overflow occur causing flash flooding.

Figure 1.1: Flash Flood at Kolej Kediaman II, Gambang Campus.

Figure 1.2: Clogged Drainage System

Before this, drainage systems in UMP were design for the Malaysia Electrical Corporation's (MEC) factory. Based on "Manual Saliran Mesra Alam" (MASMA) the design of minor drainage is for five years Average Recurrence Interval (ARI). Due to that design, drainage system in UMP is no longer possible to accommodate the capacity of runoff especially in front of Block W. That can caused floods even after a low intensity of rainfall.

Flood can also happen due the shortage of vegetation covers to intercept the precipitation from entering the river system directly. Due to this, the flood can cause significant number casualties, disease epidemics, property and crop damage and other intangible losses. By deepening and widening the drains is obviously not the best solution for this problem but it cost too much and in cases there never enough space for it.

The brilliant solution is using different approaches by focuses on the storm water control at source, retention and detention to gain maximum benefit. In this study, Hydrologic Engineering Centre Hydrologic Modelling System (HEC-HMS) had been used to analyze the rainfall-runoff. By using this software, we can determine the rainfall-runoff relationship by producing hydrograph. Therefore, this study needs in order to estimate the surface runoff from the upstream area to establish flood control at UMP Gambang Campus.

1.3 OBJECTIVE

The objectives of this study are as the following:

i. To analyse rainfall-runoff relationship using Synder and Clark Time Area method.

ii. To calibrate and validate transformation model in a sub-catchment Universiti Malaysia Pahang, Gambang Campus.

iii. To identify the most appropriate transformation method for sub-catchment of Universiti Malaysia Pahang Gambang Campus.

1.4 SCOPE OF STUDY

The scopes of this study only focus in sub-catchment area in Universiti Malaysia Pahang, Gambang Campus. In order to achieve the objectives, the scopes of this study are as the following:

i. Collect Hydrological Data which is rainfall and flow rate data of Universiti Malaysia Pahang Gambang Campus sub-catchment within the period of four months (October – December 2015).

ii. Calibrate and validate the data using HEC-HMS software.

iii. The two-transformation method which is Snyder and Clark Time Area method used to produce reliable flood flow estimation for sub-catchment of Universiti Malaysia Pahang Gambang Campus.

1.5 SIGNIFICANCE OF STUDY

From this study, the relationship between rainfall and runoff can be obtained using HEC-HMS software. Besides that, the comparison between two method which is Snyder and Clark Time Area method that used to analyzed relationship between rainfall and runoff can be determined. So, this study can be reference for future researcher to analyze the flood by using the data collected and appropriate method in sub-basin of Universiti Malaysia Pahang, Gambang Campus.

It is important to do this study because we can determine the rainfall quantity and the runoff capacity. The relationship between rainfall-runoff also can be determine. This study can provide Jabatan Pengairan dan Saliran (JPS) all the information needed in design facilities to reduce any damage cause by flood. Data from this study might as a guideline during design the drainage system and future development in UMP. The problem like flash flood and insufficient capacity of drainage can be prevented.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Situated between 1° and 6°N, Southeast Asia has long experienced a monsoon climate with dry and wet season throughout the year. Malaysia has 189 water basins with a mean annual rainfall precipitation around 2500 mm and locally in excess of 5000 mm, the very intense rainstorms in the steep mountains of Malaysia have caused frequent and devastating flash floods. In the valleys floodwater spread over very wide flood plains developed for agriculture, predominantly rice paddies and oil palm.

Flooding has been a major concern in recent decades. Malaysia can be categorized as one of the developing countries in Asia that is rapidly emerging in industrialization. Urbanization and deforestation exacerbate flooding problem due to the increased runoff from the impervious areas. The industrial developments fostered a new way of urban life and flood control in Malaysia is undergoing significant changes. There has been major and tragic flooding in Malaysia since 1926.

The combination of natural and human factors has produced different types of floods such as monsoon and flash flood. It make that flood is a major disaster in Malaysia due to regular and heavy rainfall every year from October to March. Flood occurrence has become a national issue as it threatens life and property and disrupts social and economic activities.

2.2 TYPE OF FLOODS IN MALAYSIA

Malaysia is a country that is freed from natural disaster such as earthquakes, volcano and typhoon. The most common natural disaster experiencing in Malaysia is flood. The type of flood occur in this country are monsoon flood and flash flood. It is difficult to distinguish between floods happen because of nature or human. In Malaysia, floods are caused combination of natural and human factors, flash flood mostly in urbanized catchment due to human factor. Then, monsoon flood which are more common and severe largely attributed to the physical geography.

Monsoon floods characterized by low intensity long duration rainfall and unpredictable flash flood characterized by high intensity short duration rainfall (Lee Loke Chong, 2008). The northeast monsoon flood occur during the months of November to March with heavy rains to the east coast states of the Peninsula, northern part of Sabah and southern part of Sarawak. Monsoon floods are brought by monsoon winds which deposit heavy rainfall during southwest monsoon season during May to September. They are seasonal in nature, of longer duration and are more severe especially during the northeast monsoon.

Flash flood is a local flood that occurred within 4 to 6 hours after a high intensity storm event usually in urbanised lowland area. Flash flood phenomenon usually is due to inability of the drainage system to fulfil the stormwater volume. Flash flood in an urbanised area such as Kuala Lumpur has higher frequency and magnitude than in rural settlement. Flash flood can be the most dangerous kind of flood because they combine the destructive power of a flood with incredible speed and unpredictability. It happen when the ground under a storm becomes saturated with water so quickly that it cannot be absorbed, hence the runoff collects in lowland area and flow downstream become suddenly in rising water.

As reported in news on 12 November 2015, flash floods happen in several areas in Kuala Lumpur. Among the areas affected were Kampung Datuk Keramat, Jalan Semarak, Jalan Sentul, Jalan Kampung Pandan, and Jalan Ampang. However, the flood waters receded about half an hour later.

2.3 FACTORS OF FLOOD

Flooding can be caused by many factors. The factor of flooding can be by natural factor, man-made or any combination of these two factors. Reported by Department of Irrigation and Drainage Malaysia, there are two major categories of causes of flood in Malaysia, which are natural factor and human activities. The first catagory is natural factor, the heavy rainfall in Malaysia especially in monsoon season caused flash flood and resulting in stagnant water. The second category that Department of Irrigation and Drainage (DID) categorized of factor of flood is man-made category. It is including dumping of solid waste into river, sediment from construction site and increased impervious area.

Flash flooding have many reason for it occurrence, one of them is the due to clogging of drain cause by human activities. Increase the density of population contributes to high disposal of waste and will cause pollutions to that area. The rubbish and sediment from construction works and soil erosion will cause highly pollution and prevents the smooth flow of water. When heavy rainfall occur, the drain unable to support the amount of water thus an overflow occur causing flash flooding.

Soil and rock type can also influence what happens to precipitation when it reaches the ground. Impermeable soils and rocks such as clay or shale do not allow water to infiltrate, this forces water to run off reducing river lag times and increasing flood risk. Permeable rocks allow water to infiltrate into them. If permeable rocks allow water in through cracks, fissures and bedding planes but not through their pores they are said to be pervious (such as limestone). Porous rocks allow water to penetrate into their pores such as sandstone. Decreasing amount infiltration of the rainfall causing the water accumulates and flash flooding occurs.

Other than that, the increased of floods occurrence especially in urban area are largely due to urbanization process. Human life cannot get away from the process of urbanization as people always want advancement and want to enjoy surviving. That result in increase of impervious surface which shortened the time of concentration and increase the magnitude of the runoff discharge. Figure 2.1 show the peak in urban area

is higher due to impervious area and water flow faster in concrete drain. The whole urban system is designed to move water from the surface into underground pipes and away from urban area which have value. This also can lead to floods in the rural area.

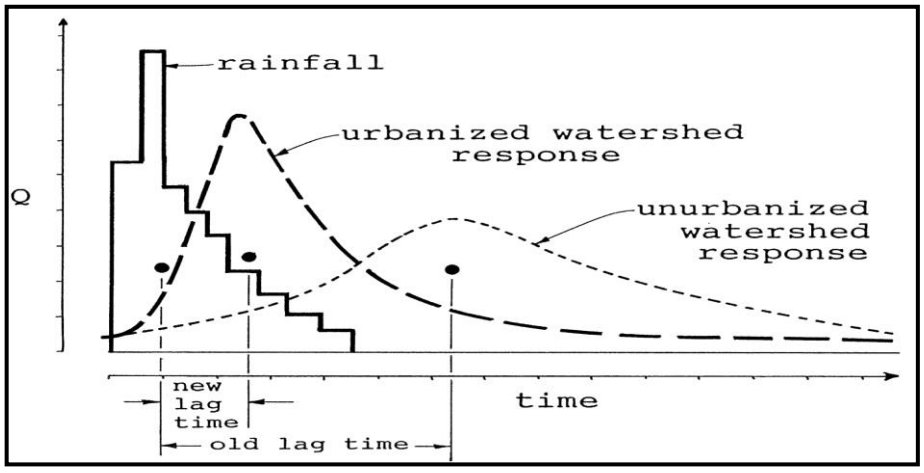

Figure 2.1: The peak in urban area is higher due to impervious area and water flow faster in concrete drain.

Source: Leopold, L.B. (1968)

2.4 EFFECT OF FLOOD

There are two categorized in effect of flood which is tangible and intangible effects. Effect of flood that can cause monetary loss can be referred as tangible effects or can be described as direct effects of flood that contact with human and property. Tangible effects have an impact on the physical assets such as human and infrastructure. While, intangible effects refer to the flood impact that cannot cause monetary loss. This mean that intangible or indirect effects are like interruption of production of goods and services that happen due to interruption of transport, utility services and markets.

When flood happen, many structure have been totally submerged by flood water. The structures including flood wall and bridges that are built for living and businesses are completely destroyed by flood. The damage of building and structure